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IDENTIFICATION OF STEELHEAD STOCKS IN THE COMMERCIAL NET FISHERY OF THE SOUTHERN BRITISH COLUMBIA COAST

by

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Fisheries Management Report No. 81
1984

Canadian Cataloguing in Publication Data

Parkinson, Eric A. (Eric Arthur), 1950-

Identification of steelhead stocks in the commercial net fishery of the southern British Columbia coast

(Fisheries management report, ISSN 0705-5390 ; no. 81)

Bibliography: p.
ISBN 0-7726-0247-6

1. Steelhead (Fish) - Identification. 2. Salmon-fisheries - British Columbia. I. British Columbia. Fisheries Branch. II. Title. III. Series: Fisheries management report (British Columbia. Fisheries Branch) ; no. 81.

SH167.T86P37 1985 639.3'755 C85-092064-7

ABSTRACT

Parkinson, E. A. 1984. Identification of steelhead stocks in the commercial net fishery of the southern British Columbia coast. B. C. Ministry of Environment, Fisheries Management Report No. 81, 15 p.

Biochemical variants detected by electrophoresis were used to identify three major groups of steelhead stocks as they passed through the southern B. C. commercial net fishery. In 1978-80 an average of 58% of the steelhead intercepted in this fishery were from interior fall-run stocks native to the Thompson and Chilco rivers. The proportion of interior stocks increased as the season progressed from 33% in July to 81% in September. Coded wire tag data was used to confirm the absence of large numbers of analogous stocks from upper Columbia River tributaries.

ACKNOWLEDGEMENTS

Support for this study was provided under the joint federal-provincial Salmonid Enhancement Program.

Assistance in sample collection and laboratory processing was provided by J. Steinberg, L. Hildebrand, M. Winsby and I. Keith. I. Warner typed the manuscript. A. Tautz, P. Slaney, J. Hume and R. Hooton provided many useful comments during the editing and review process.

INTRODUCTION

Steelhead harvested as incidental catches in the commercial salmon fisheries in southwestern British Columbia fall into three broad categories. Summer-run steelhead enter coastal streams between May and September. Fall-run populations return to the upstream tributaries of the Fraser and Columbia rivers between August and November. Winter-run populations also return to coastal streams but enter freshwater between November and May. All exit as kelts following spawning in the spring. According to Canadian catch statistics, three major net fisheries, Johnstone Strait (areas 12, 13), Juan de Fuca Strait (area 20) and the Fraser River (area 29) (Fig. 1) accounted for over 75% of the Canadian commercial catch of steelhead in this area during the 1977-80 period. Most of these steelhead are probably returning to the Fraser River and to streams entering Georgia Strait and Puget Sound but the catch could potentially include significant numbers of fish from Washington, Oregon, Idaho and California.

Naturally occurring variation in scale patterns (Cook 1982, Cook and Lord 1978, Major et al. 1978, Bilton 1972), morphological traits (Fukuhara et al. 1962), and the elemental composition of vertebrae (Mulligan et al. 1983) has been used to identify anadromous salmonid stocks in mixed fisheries. In this study, previously reported (Allendorf 1975, Huzyk and Tsuyuki 1974, Parkinson 1980) differences in gene frequencies at two electrophoretic loci were used to determine the proportion of fall-run steelhead stocks in the commercial catch. A difference at a third locus was used to separate the Fraser fall-run stocks into two major groups of populations. Protein variation has been employed for stock identification in cases where consistent differences in gene frequency between stocks were present (Grant et al. 1980, Milner et al. 1980, Nyman and Pippy 1972, Fournier et al. 1984).

Artificial tags have also been utilized to identify stocks in mixed stock fisheries both on their own (Hartt 1962) and as a complement to other methods (Cook and Lord 1978). Many anadromous salmonids, including steelhead, have been tagged with coded wire tags (CWT) and an extensive recovery program was undertaken in the commercial fishery by the Canadian Department of Fisheries and Oceans. CWT recoveries offer a means of estimating the catch of certain stocks which cannot be identified electrophoretically.

MATERIALS AND METHODS

Baseline data for this study was collected in B. C. by Parkinson (1980) and in the northwest United States by Allendorf (1975). Three enzyme loci were identified as having the most potential for stock identification. The proportion of variants at the LDH and SOD loci was very different in coastal (summer and winter run) and interior (fall-run) populations. Variants at the

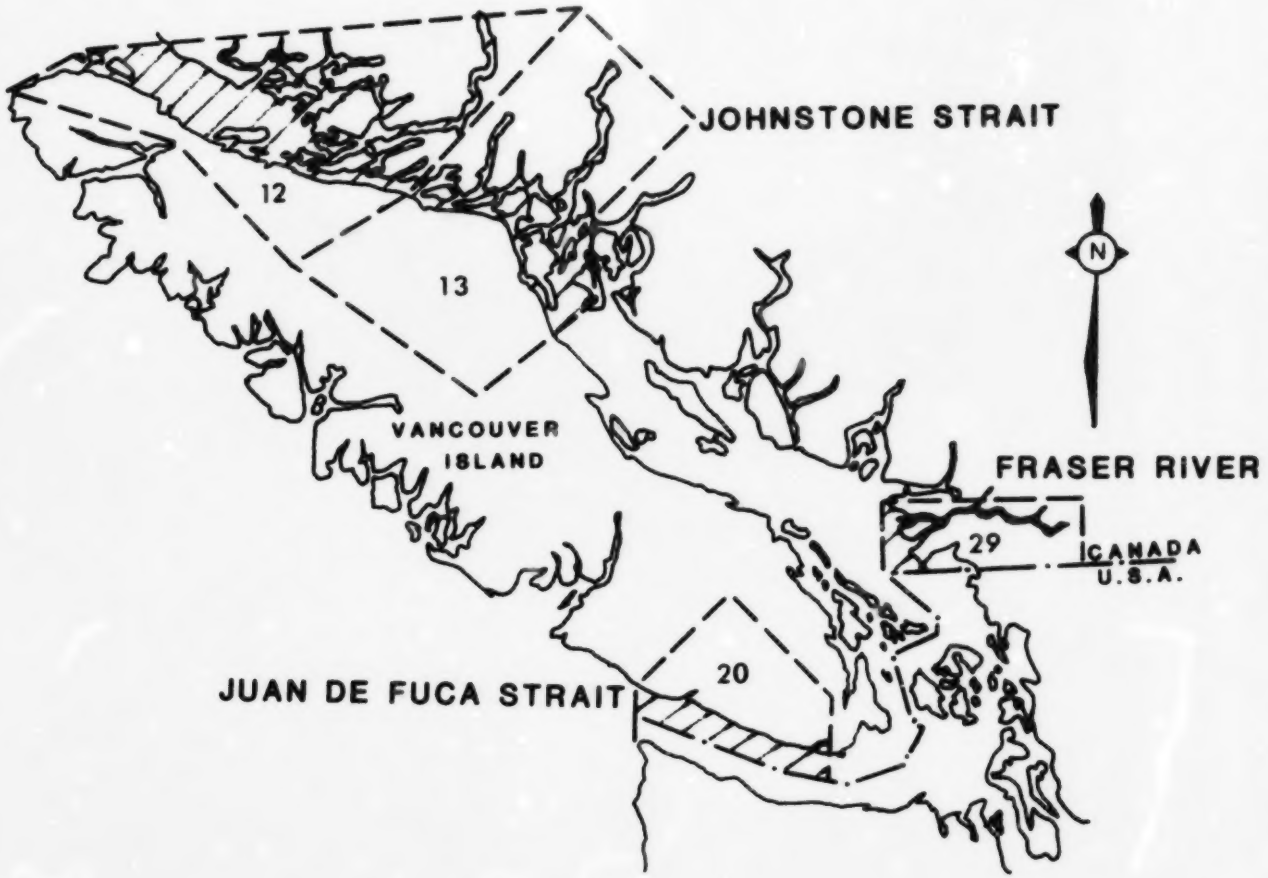

Fig. 1. Commercial fishery areas involved in this study. Numbers refer to Canadian Department of Fisheries and Oceans statistical areas.

AGP locus, which were almost absent in most samples, were present at a much higher frequency in samples from one of the two major fall-run populations (Chilcotin) in the Fraser River. No loci were identified which could be used to distinguish coastal summer and winter run fish. The baseline genotype frequency of a stock was the unweighted mean of the sampled populations within the geographic area occupied by the stock.

Commercial fishery samples (liver and muscle) were collected from fishermen or collector boats making deliveries to various fish processing plants in the Vancouver, B. C. area except for 1977 and 1978 when some samples were collected directly from fishermen on the fishing grounds. Samples were collected up to 3 days after death from fish which had been iced or kept in supercooled brine. Approximately .5 cc of each tissue was taken with a 10 mm cork borer and put directly into 13 x 75 mm plastic test tubes to which approximately .25 cc of water was added. The test tubes were capped and placed on ice for transport to the electrophoresis laboratory where they were frozen at -20^{o} C for up to 6 months prior to analysis. Up to 100 samples a month were to be collected from each area but in most cases, this goal was not met because of short openings, few deliveries and exceptionally low steelhead to salmon ratios.

Electrophoretic analyses were conducted using equipment and methods described by May et al. 1979. Two buffer systems were used. The first, after Ridgeway et al. (1970) (electrode buffer .06M LiOH, .3M boric acid (pH 8.3), gel buffer, .005M citric acid, .03M tris (pH 8.3)), was used for LDH and SOD. The second, after Shaw and Prasad (1970) (.155M tris, .043M citric acid (pH 7.0), full strength for the electrode buffer and diluted 1:15 with distilled water for the gel buffer), was used for MDH, IDH and AGP. Staining solutions were adapted from Allendorf (1975). All of the variants used in this study have been previously reported. The Mendialian inheritance of the various alleles has been documented by Allendorf (1973) for liver LDH, Cederbaum and Yoshida (1972) for SOD, and Allendorf (1975) for white muscle AGP.

The mixed stock proportions were calculated using a maximum likelihood formula developed by Milner et al. (1980) and used by Grant et al. (1980). A good formula to estimate the variances applicable to the proportions of each stock in the mixed fishery is not available at the current time. In some cases, the variances of the monthly estimates of the proportions of each stock is expected to be large because of small commercial fishery sample sizes. In such cases, the consistency of results between years and months gives some additional confidence in the estimates.

Catch statistics were obtained from Department of Fisheries and Oceans (DFO) data. Raw DFO data was adjusted to reflect the true catch of steelhead using the methods of Oguss and Evans (1978). DFO data has to be adjusted because only

steelhead sold as steelhead are included in the catch statistics and many steelhead are either sold as salmon or kept for personal use by fishermen. Using the monthly maximum likelihood estimates of the proportion of each stock in the fishery, monthly catches were apportioned to the three stocks. Total catches of each stock were the sum of the monthly estimates.

A large number of steelhead, particularly hatchery steelhead, have been tagged with CWTs in recent years. Details of the origins of various tag codes are published annually (Anonymous, 1980) and annual reports of an extensive tag recovery program are also available. CWT data indicated the presence of Upper Columbia (above Bonneville Dam) fall-run steelhead in both Juan de Fuca and Johnstone straits. Most of these fish will be identified as Thompson River stock in the mixed fishery analysis because they have a low frequency of SOD and AGP variants and have a high frequency of the LDH variant (Milner et al. 1980). No attempt was made to assign these fish to individual stocks within the Upper Columbia because the number of tags recovered was too small. The total number of Upper Columbia tags (from all stocks) recovered in each fishery was calculated as the product of the number of actual tag recoveries and an expansion factor (catch:sample ratio) which accounts for the fact that only a proportion of the catch is examined for tagged fish. The total number of Upper Columbia steelhead was then calculated by dividing the total tag numbers by the proportion of Upper Columbia steelhead that are coded wire tagged. The coho catch:sample ratio was used because the catch:sample ratio for steelhead was very low since many steelhead were sold as salmon in catches which were not examined for tags. I assumed that a tagged steelhead had the same probability of recovery as a tagged coho because most unreported steelhead were sold as coho salmon (Oguss and Evans 1978). The proportion of coded wire tagged fish in the Upper Columbia stocks was measured in the Bonneville pool commercial fishery (200 km upstream from the mouth of the Columbia River) and includes data for the months of August, September and October (Don Park, National Marine Fisheries Service, pers. comm.). As pointed out by Park, the Bonneville pool fishery is probably selective for heavily tagged roups of steelhead which were trucked downstream and released below Bonneville Dam. The minimum proportion tagged occurred in 1978 before most of the trucked fish were due back and I have used this to calculate the maximum contribution of upper Columbia steelhead. Despite the uncertainties in this data, it is the best available. Attempts to calculate the proportion tagged from smolt release data experienced problems with large numbers of release groups and the unknown contribution of wild smolts. With such small numbers of tag recoveries, the error on these estimates is expected to be large. No attempt was made to calculate this error, however, because of unknown errors and biases in both the coho catch:sample ratio and the proportion of steelhead tagged in the Bonneville pool.

The number of Coquihalla stock summer steelhead caught in the Juan de Fuca/Johnstone Strait fishery was also estimated from CWT recoveries in order to estimate a harvest rate for a summer-run stock in this vicinity. The Coquihalla stock was used because it is the only extensively tagged summer-run stock in the Johnstone/Juan de Fuca Strait area. Fraser River catches were not estimated because of possible difficulties in recovering tags in this area. Only 1980 data was used because this was the first year in which there were substantial tagged hatchery returns to the Coquihalla.

RESULTS

Baseline Data Summary

The cline in LDH and SOD gene frequencies are both very sharp and coincide with the boundary between coastal stocks (winter- and summer-run) and interior stocks (fall-run) (Fig. 2). The clines occur in a canyonous area of the Fraser River where most tributaries are short and steep and contain few steelhead. Only the Coquihalla and Nahatlatch populations are not clearly identified as either interior or coastal stocks. The Coquihalla and all tributaries downstream contain only summer and winter run fish. The Stein and Nahatlatch may contain either or both winter and fall run stocks but other upstream tributaries probably contain only fall run fish. The only upstream tributaries that contain appreciable numbers of steelhead are the Thompson, Chilcotin, Bridge and Seton river systems in that order of importance. Adult population estimates made by regional fisheries biologists are poor but are in the order of 3-5 thousand for the Thompson, 3-5 hundred for the Chilcotin and one hundred for the Bridge and Seton systems.

AGP gene frequencies differ markedly between the two major interior stocks, the Thompson and Chilcotin (Fig. 2). The small interior stocks can be grouped with the Thompson since none carry the AGP variant in appreciable frequencies. High frequencies of the AGP variant (up to .23) are also found in some populations of summer steelhead in the Columbia drainage. These stocks, mostly derived from the Skamania, Washington hatchery stock have been extensively tagged but only two tags in three years have been recovered in the study area, implying that these stocks are, for the most part, absent.

Mixed Fishery Analysis

The Fraser River (area 29) fishery was sampled in two years, 1977 and 1980. In both years various factors, such as non-reporting of steelhead, the small size of each delivery and a low ratio of steelhead to salmon, made it difficult to obtain samples. Both samples consisted almost entirely of interior fall run fish, mostly from the Thompson River. This conclusion may be erroneous since the Coquihalla stock, the major summer-run stock in the lower Fraser, does not have genotype frequencies typical

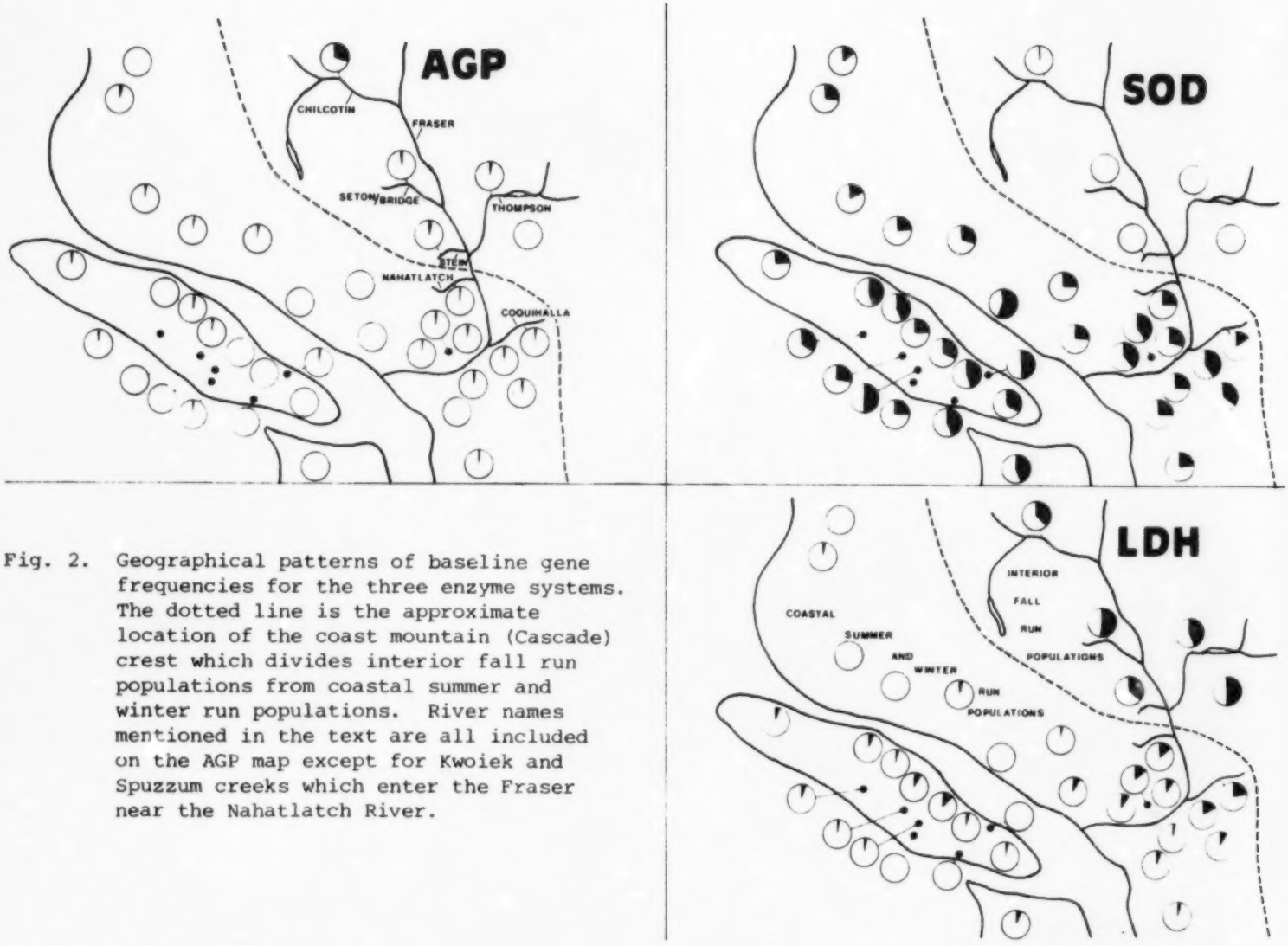

Fig. 2. Geographical patterns of baseline gene frequencies for the three enzyme systems. The dotted line is the approximate location of the coast mountain (Cascade) crest which divides interior fall run populations from coastal summer and winter run populations. River names mentioned in the text are all included on the AGP map except for Kwoiek and Spuzzum creeks which enter the Fraser near the Nahatlatch River.

of most coastal streams. The use of Coquihalla genotype frequencies (instead of average coastal frequencies) as baseline data produced very little change in the estimates. In the calculation of the total catches for each stock, I have assumed that the entire Fraser River catch is made up of 10% Chilcotin, 88% Thompson and 2% coastal stocks, which is the average of the 1977 and 1980 values using Coquihalla baseline genotype frequencies.

Johnstone Strait (Areas 12 and 13) was the most extensively sampled of the three fisheries. In 1977 not enough samples were obtained to calculate monthly estimates, but substantial numbers of interior fish were present in all years. The pattern of catches is similar in each of the three years for which monthly data is available (Fig. 3). High catches, corresponding to high CPUE's rather than high effort (Oguss and Evans 1978) were made in July of each year. Catches and CPUE, drop in August, may peak again in September, and drop with decreasing fishery effort in October. Unlike the Fraser, interior fish are almost equally divided between the Chilcotin and Thompson stocks. In 1978 and 1980, there is an indication that more of the interior fish are from the Chilcotin River early in the season, implying that the Chilcotin run is somewhat earlier than other interior runs. The July peak appears to be caused by large numbers of available steelhead, particularly coastal stocks, rather than large effort at this time. These fish may be from a number of sources, existing kelts, entering summer-runs or fish resident in the fishing area, but I could not distinguish between these possibilities. Attempts to identify kelts on the basis of gonadal development failed because most fish could not be cut open and examined carefully. There were no external characteristics which could be used to reliably separate kelts from immature steelhead.

The Juan de Fuca fishery was only sampled in two years and differed from the Johnstone Strait fishery in that there was no July peak and a higher proportion of the total catch was made up of interior stocks. The lack of a July peak was due to a lack of effort since catch per delivery was high early in the season. As in Johnstone Strait, less than half of the August catch is from interior stocks but by September almost all fish are from interior stocks. A higher proportion of interior fish in Juan de Fuca Strait appear to be Thompson stock.

In terms of catch, the majority of steelhead caught in Johnstone Strait were from coastal stocks but interior fall-run fish predominated in the Juan de Fuca Strait and Fraser River fisheries (Table 1). Steelhead are also intercepted on the American side of Juan de Fuca Strait and southern Georgia Strait but are not reported in the American catch statistics because it is illegal to retain them. Since the American and Canadian catches of sockeye in the Juan de Fuca/Fraser River area are equal according to an international treaty, the American Juan de Fuca was assumed to be equal to the Canadian Juan de Fuca/Fraser

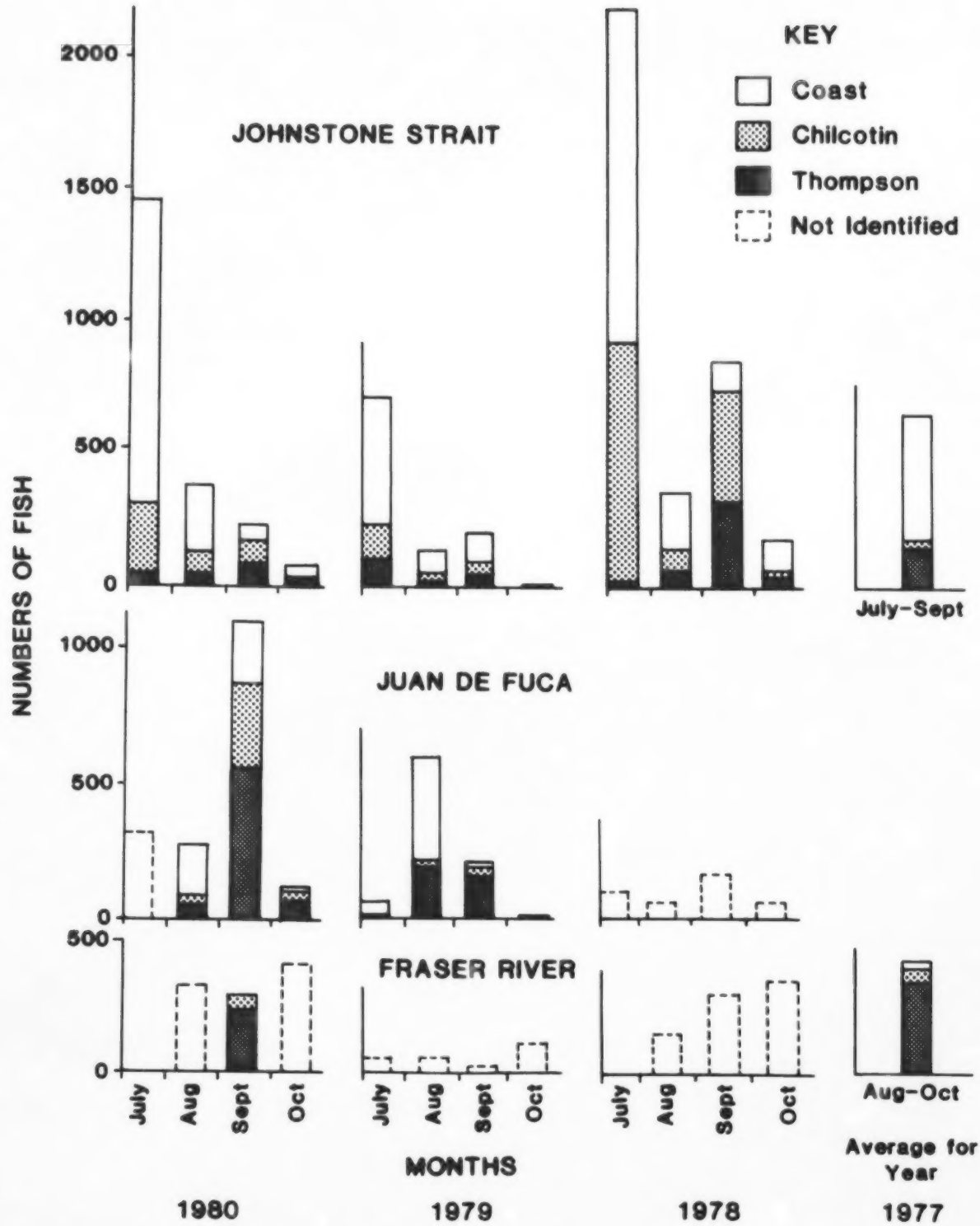

Fig. 3. Temporal distribution of the three stocks in the three statistical areas involved in this study.

steelhead catch. The stock composition of the American catch was assumed to be the same as the Canadian Juan de Fuca catch (Table 1). It should be noted that the American Juan de Fuca catch makes up a large proportion of the total Thompson estimate. The accuracy of the total Thompson estimate is therefore highly dependent on the accuracy of the assumption concerning the American Juan de Fuca catch of steelhead. The number of Upper Columbia steelhead in the study area (calculated in Table 2) is small when compared to the numbers of Thompson River steelhead, accounting for a maximum of about 14% of the estimated Thompson catch in Table 1.

Table 1. Average stock composition in terms of numbers per year over the 1978-80 period for commercially caught steelhead in the Johnstone Strait, Juan de Fuca Strait and Fraser River areas. Data in this table has been adjusted by the method of Oguss and Evans (1978). The calculation of the upper Columbia contribution is detailed in Table 2.

	Johnstone	Juan de Fuca		Fraser	TOTAL
		Canadian	American		
TOTAL	2810	1100	1980	880	6770
Coast	1630	430	780	20	2860
Chilcotin	880	170	300	110	1460
Thompson (Initial estimate)	300	500	900	750	2450
Upper Columbia contribution					
Best estimate	49	53	53	0	
Maximum estimate	109	114	114	0	
Thompson (Revised estimate)					
Best estimate	251	447	847	750	2295
Minimum estimate	191	386	786	750	2113

Table 2. Detailed calculation of the contribution of steelhead from the Upper Columbia River drainage to the commercial catch in the Johnstone and Juan de Fuca Strait areas using CWT data.

Area	Year	Tags Recovered	Coho C/S Ratio	Total Tags	Tagged (Bonneville Pool)		Total Catch
Best Estimate							
Johnstone	1978	0			.093		0
	1979	4	3.8	15.2	.191		79
	1980	7	2.17	15.19	.224		67
						Mean	49
Juan de Fuca	1978	0			.093		0
	1979	6	3.7	22.2	.191		116
	1980	4	2.4	9.6	.224		43
						Mean	53
	Total per year (both areas) - - - - - - - - -						102
Maximum estimate - assuming equal Canadian and American catches in Juan de Fuca and a minimum (1978 value) proportion tagged in Bonneville pool.							
Johnstone	1978	0			.093		0
	1979	4	3.8	15.2	.093		163
	1980	7	2.17	15.19	.093		163
						Mean	109
Juan de Fuca	1978	0			.093		0
	1979	6	3.7	22.2	.093		239
	1980	4	2.4	9.6	.093		103
						Mean	114
	American Juan de Fuca - - - - - - - - - - - -						114
	Total per year (both areas + American) - -						337

Eleven Coquihalla CWTs recovered in 1980, all in July and all but two of them from Johnstone Strait, were used to estimate the harvest of this stock in the Johnstone/Juan de Fuca Straits fishery. Ten tags were from fish released as smolts 2 years previously and were, therefore, probably on their maiden spawning run rather than exiting as kelts. From DFO statistics,

the coho catch/sample ratio in the CWT recovery program was 2.21 in July, 1980 and in the Coquihalla itself and the proportion of tagged fish in the angler catch in the summer of 1980 was .53 (P. Caverhill pers. comm.). The total number of Coquihalla stock caught in these fisheries was, therefore, 11 x 2.21/.53 = 46 fish. Since the total return to the Coquihalla River in 1980 was approximately 400 summer steelhead, the harvest rate in these fisheries was 46/446 or approximately 10%. This is a maximum estimate since additional fish were removed from this population in the Fraser River, commercial and Indian fisheries before the population returning to the river was estimated.

DISCUSSION

Approximately 60% of steelhead intercepted in the 1978-1980 commercial fishery were from interior stocks which enter freshwater shortly after the peak in the commercial fishery effort. The number of interior steelhead from American stocks in the upper Columbia was small compared to the numbers of Canadian steelhead from the upper Fraser. Harvest rates on the two upper Fraser stocks do not appear to be equal. If estimates of the relative population sizes for the Chilcotin and Thompson rivers are correct, then Chilcotin steelhead are disproportionally represented in the commercial fishery, particularly in the early season Johnstone Strait catch. Catches from later in the season have a higher proportion of Thompson fish indicating that the Chilcotin run may pass through the commercial fishery earlier and be harvested at a higher rate than the Thompson run. In a number of anadromous salmonids, stocks with longer river migration routes enter freshwater earlier (Henry 1961, Saunders 1967). The Chilcotin migration route is almost twice as long as that of the Thompson stock.

Interior stocks from the upper Columbia seem to be capable of sustaining very high harvest rates (80%) under pristine conditions (Bjornn 1977). Harvest on the upper Fraser stocks is probably approaching this rate. If estimates of escapements to the river of 400 and 4000 for the Chilcotin and Thompson stocks are correct, then the commercial harvest rates are about 80% and 40%, respectively. Current estimates of the sportfish harvest are about 40 and 1500 fish, respectively (Ford 1982, Billings 1983), giving a total estimated harvest rate of 82% and 63% for these two stocks. One of two conclusions therefore has to be made; either harvest rates on these stocks are approaching maximum acceptable levels or current estimates of population sizes are too low.

The origin of the coastal fish is still in doubt. Most are caught during the July peak in catches which is present in Johnstone but not Juan de Fuca Strait. June and July sample sizes in Juan de Fuca Strait are very small due to a lack of effort rather than a low catch per unit effort. The timing of

the peak, the depressed state of summer steelhead runs, and the mixture of stocks, all seem to indicate that the early peak consists mostly of exiting kelts from all stocks. Of the 45 CWTs recovered in these areas during the 1978-80 period, however, only one was a winter steelhead. In contrast 18 tags were recovered from just 2 enhanced B.C. summer steelhead stocks (Coquihalla and Stamp) and 21 tags were recovered from fall-run upper Columbia stocks. No Canadian winter steelhead tags have been recovered in these fisheries. Winter run steelhead have been tagged in a number of Georgia Strait streams in a tagging program at least as extensive as that for summer steelhead. Only two U.S. coastal tags, one summer and one winter run, have been recovered in these fisheries. Washington State has a limited tagging program but the lack of tags may also indicate that U.S. fish enter and exit through Juan de Fuca Strait where the early fishery is absent. In summary, the tagging results indicate that the harvest rate on summer steelhead is high relative to that of winter run stocks. Winter run stocks may, however, outnumber summer run stocks in terms of actual numbers of fish caught. The harvest rate on the Coquihalla summer-run steelhead stock was approximately 10% in 1980 in the Johnstone/Juan de Fuca Strait commercial fishery. If this is typical of the commercial fishery harvest rates on summer steelhead stocks within Georgia Strait excluding the Fraser River, then the commercial fishery alone is not large enough to result in overharvest of these stocks.

Both the catch and harvest rates of American fall run stocks were probably low in these fisheries. The maximum total harvest of interior (upper Columbia) steelhead is less than 350 per year compared with counts of over 100,000 per year (1978-79) at Bonneville Dam (Anonymous 1979). The presence of a number of Upper Columbia steelhead in the B.C. commercial fishery does not, therefore, indicate that a large proportion of these fish migrate through Johnstone and Juan de Fuca straits. The large size of Upper Columbia populations relative to those in the Upper Fraser suggests that only a small fraction of the Upper Columbia stock would have to migrate inside Vancouver Island in order to account for the number of upper Columbia steelhead present in the commercial fishery. Most of these fish probably migrate down the west coast rather than the east coast of Vancouver Island where these fisheries are located. Twenty-five percent of the southwestern British Columbia steelhead catch in the 1978-80 period was from the west coast of Vancouver Island but the majority of this catch (~ 75%) was made up of coastal steelhead from Barkley Sound. American coastal stocks, particularly those from Puget Sound, could potentially be heavily intercepted in Canadian fisheries but a lack of CWT recoveries indicates that they are not.

A lack of Thompson CWT recoveries in the commercial fishery in recent years casts some doubt on the above analyses. In 1980 and 1981 for example, 11 CWT's were recovered from the sports fishery in the Thompson River (Ian McGregor, per. comm) but only 3 tags were recovered in the commercial fishery. These

numbers cannot be directly compared because the catch to sample ratio is unknown in the sport fishery but there is an indication that either CWT's are not recovered effectively in the commercial fishery or the catch of Thompson fish is somewhat lower than was calculated using the electrophoretic method. Ineffective recovery of CWT's would, of course, mean that the commercial harvest of Upper Columbia and Coquihalla steelhead was greater than in the preceeding calculations. In 1985, a monitoring program on the Fraser River commercial and native fisheries will attempt to assess the seriousness of this problem.

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